Historical temporal trends in monthly, seasonal, and annual mean, minimum, and maximum streamflows from the Okanagan River watershed in south-central British Columbia, Canada

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Existing and projected temporal trends for the timing and magnitude of streamflows in western North America have received significant scrutiny over the past two decades (see, e.g., ref. [1-18]). There continues to be active debate in the literature as to whether any hydrologic changes are occurring, and if so, whether they can be ascribed to natural cycles or human-induced alterations of the climatic system. In terms of water management, the primary concerns involve an earlier melt of the winter snowpack, leading to an earlier (and potentially more intense) freshet peak with concomitant risks of flooding, followed by lower late summer flows that can pose risks to ecological functions and a reduced availability of water for agricultural and domestic/industrial uses. For some regions of western North America, decreasing absolute and/or fractional streamflows have already been reported during the late spring and summer periods [1,4,6,7], with increasing absolute and/or fractional streamflows during the late winter and early spring periods [2,4-7,15], and an earlier arrival of the spring runoff peak [3-6,9-11,13-16].

In the Okanagan River watershed (Figure 1) of south-central British Columbia, Canada, a number of studies have investigated temporal trends and patterns in climate and hydrology [6,18-32]. The results and interpretations of any historical and/or projected hydrologic changes – and the risks they pose to water management systems – appear to vary between research groups, warranting additional independent investigations. As part of the current work, we examine historical trends in monthly, seasonal, and annual mean streamflows, as well as minimum and maximum monthly streamflows, at nine hydrometric stations in the Okanagan River watershed (Figure 2). Streamflow data was obtained from the online Environment Canada/Water Survey of Canada database [33] (Table 1).

The two mainstem stations on the Okanagan River (08NM050 [Okanagan River at Penticton] and 08NM002 [Okanagan River at Okanagan Falls]) downstream of Okanagan Lake are classified as regulated systems, as are the tributary stations 08NM116 (Mission Creek near East Kelowna) and 08NM037 (Shatford Creek near Penticton). All other stations are natural hydrologic systems under the Environment Canada classification system. The stations under study are located throughout the Okanagan River watershed without significant areal bias. An additional station on the Okanagan River at

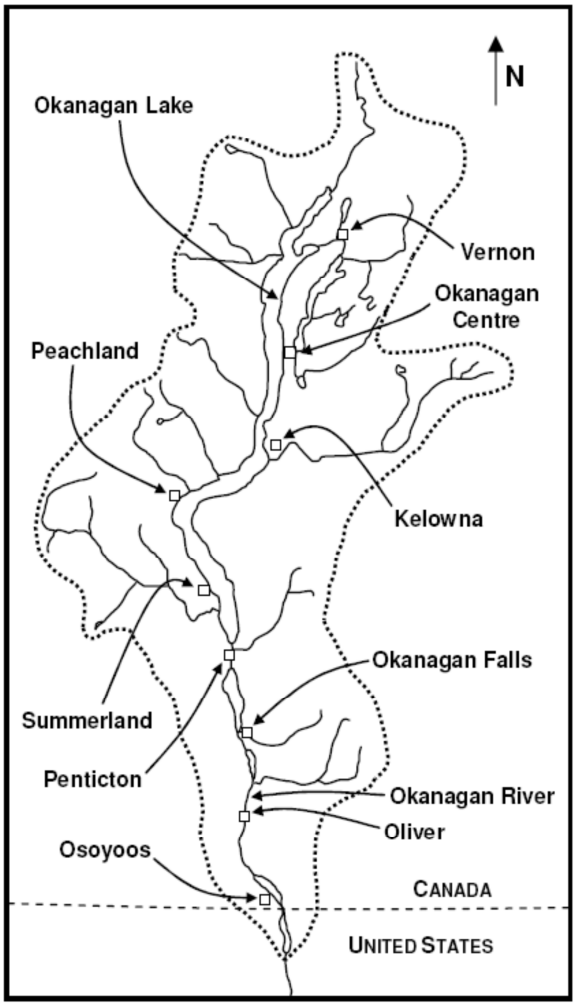

Figure 1. Schematic map of the Okanagan Valley watershed showing locations of major municipalities, lakes, and rivers.

Table 1. Details of the hydrometric monitoring stations under consideration.

Name	ID	Lat. (N)	Long. (W)	Gross drainage area (km^2)	Record length	Regulation type
Coldstream Creek above municipal intake	08NM142	50°15'28"	119°4'55"	60.6	1968-2010	natural
Whiteman Creek above Bouleau Creek	08NM174	50°12'44"	119°32'19"	114	1971-2010	natural
Mission Creek near East Kelowna	08NM116	49°52'44"	119°24'47"	795	1967-2010	regulated
Camp Creek at mouth near Thirsk	08NM134	49°42'40"	120°0'30"	34.6	1966-2010	natural
Two Forty-One Creek near Penticton	08NM241	49°39'5"	119°23'30"	4.50	1984-2010	natural
Okanagan River at Penticton	08NM050	49°29'44"	119°36'55"	5980	1922-2010	regulated
Shatford Creek near Penticton	08NM037	49°25'42"	119°44'57"	101	1966-2010	regulated
Okanagan River at Okanagan Falls	08NM002	49°20'26"	119°34'40"	6720	1915-2010	regulated
Vaseux Creek above Solco Creek	08NM171	49°14'58"	119°19'16"	117	1971-2010	natural

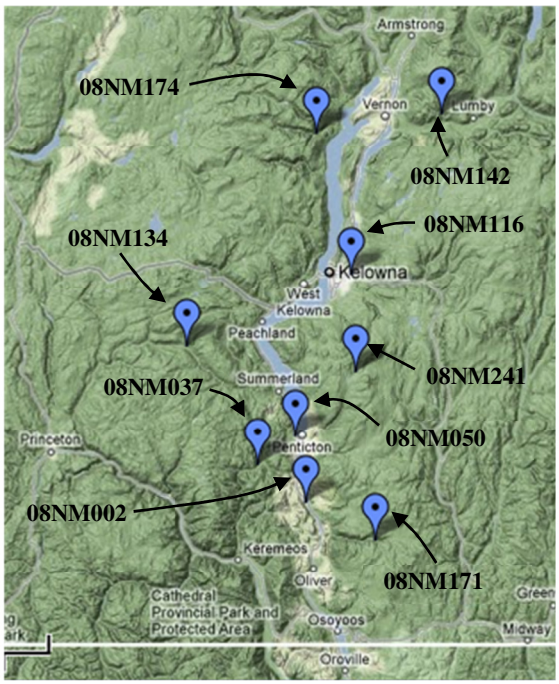

Figure 2. Locations of the hydrometric monitoring stations.

Oliver (08NM085) was considered in our previous works [19,20], and is not re-analyzed here. Record lengths vary from 27 (08NM241) to 93 (08NM002) years. Gross drainage areas range from 4.5 (08NM241) to 6720 (08NM002) km^2.

Statistical analyses of streamflow data were conducted using the nonparametric Mann-Kendall test for the trend and the nonparametric Sen's method for the magnitude of the trend [34-39]. Details of the non-parametric Mann-Kendall test statistics for historical temporal trends in mean monthly, seasonal, and annual streamflows and monthly minimum and maximum streamflows are given in Tables 2 through 4. An overall summary of significant hydrologic trends and their direction is provided in Table 5. Mean monthly streamflows, as well as mean monthly minimum and maximum flows, at each station over their respective available hydrometric records are shown in Figure 3.

None of the stations exhibit any significant changes in mean annual flows, consistent with our prior conclusions at other stations in this region [19,20], and in contrast to previous claims of reductions in annual mean runoff reported for streamflows in the Okanagan River watershed [6]. Both of the mainstem Okanagan River stations (08NM050 and 08NM002) have significantly increasing mean streamflow trends during the July-September seasonal period. Stations 08NM050 and 08NM174 (Whiteman Creek above Bouleau Creek) have significantly decreasing mean streamflow trends during the October-December and July-September seasonal periods, respectively.

Five of the nine overall stations (08NM142 [March], 08NM174 [April], 08NM116 [April], 08NM134 [April], and 08NM171 [April]), which includes four of the five natural (unregulated) stations, have significantly increasing mean monthly flows during the spring snowmelt period. There are significantly increasing trends in monthly mean streamflows on the two Okanagan River mainstem stations (08NM050 and 08NM002) during August and September, and during July at station 08NM050. Significantly decreasing mean monthly streamflow trends are evident at 08NM050 during November and December, and at 08NM174 during September. Scattered occurrences of both significantly increasing (08NM241 during May; 08NM002 during August; and 08NM171 during February, March, and April) and decreasing (08NM174 during August, September, and October; 08NM050 during November and December) minimum monthly streamflows are evident, although there are no clear patterns throughout the watershed, and no evidence of a consistent temporal decline in minimum monthly streamflows during the sensitive summer low flow period.

Similar results were obtained for maximum monthly streamflows in the tributary streams. Significant temporal increases are occurring at stations 08NM142 (March), 08NM174 (April), 08NM134 (April), and 08NM171 (April), with corresponding significant temporal decreases occurring at 08NM174 and 08NM171 during September. The two mainstem stations at 08NM050 and 08NM002 are exhibiting significant increases in maximum monthly streamflows between June and September at both stations, as well as during February and March at the further downstream station 08NM002. A significant temporal decline in maximum monthly streamflows is occurring at 08NM050 during November. An increase in maximum monthly streamflows during the spring snowmelt period is clear at five of the nine overall stations, and four of the five unregulated stations, consistent with the increases in mean monthly streamflows at these stations during these time periods. Increasing mean and maximum monthly streamflows on the two mainstem Okanagan River stations during the summer period appear to reflect water management policies for releases from the upstream dams, rather than any changes in watershed hydrology during this timeframe.

In attempting to determine the source of any perceived hydrologic trends, one of the critical issues that cannot be overcome is the short length of many hydrologic records. Hydrometric records that incompletely incorporate climatic cycles such as the Pacific Decadal Oscillation (PDO) [40] and the El Nino-Southern Oscillation (ENSO) will show inherent systematic biases unrelated to anthropogenic climate forcings. Furthermore, there has been extensive logging in the Okanagan River watershed over the past century (including current activity). As Figure 4 illustrates, substantial portions of the total watershed have been recently logged, and are in various stages of reforestation. Logging activities are known to significantly disrupt local and downstream hydrology [41-48], thereby altering the timing and magnitude of streamflows (particularly during the spring freshet flood and late summer low flow periods).

Human settlement has also increased rapidly in the region [19], leading to conversion of previously natural landscapes into municipal, industrial, and agricultural lands – all of which have different hydrologic signatures than the previously native systems. Consequently, without a detailed temporally and spatially resolved historically reconstructive coupled climate-hydrology-hydrogeology model for the region, it is impossible to determine whether any observed changes in hydrologic patterns result from natural climatic cycles, anthropogenic changes to the landscape, and/or anthropogenic changes to the climate. Given the complexity of such a required model to rigorously elucidate the source of any changes with the necessary statistical power, as well as the absence of available accurate historical details, it is unlikely such a model could be reliably constructed.

Overall, mean annual streamflows in the Okanagan River watershed are not exhibiting any significant time trends. No consistent declines in monthly minimum streamflows are evident at any point during the hydrologic year. Mean monthly and monthly maximum streamflows in tributary streams to the mainstem system appear to be significantly increasing over time during the spring snowmelt period of March and April. Any temporal changes in flow patterns at the mainstem Okanagan River stations likely reflect alterations in water management strategies over time at the respective upstream dams.

Table 2. Summary of non-parametric Mann-Kendall test statistics for historical temporal trends in mean monthly, seasonal, and annual streamflows at hydrometric stations in the Okanagan River watershed, British Columbia, Canada. Values are in m^3/s/year (Q) and m^3/s (B).

				Mann-Kendall trend		Sen's slope estimate					
Time series	First year	Last Year	n	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B[f]	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM142											
January	1968	2010	42	1.51	n/s	0.000	0.000	0.001	0.039	0.050	0.027
February	1968	2010	42	1.64	n/s	0.000	0.000	0.001	0.037	0.048	0.026
March	1968	2010	42	1.97	*	0.001	0.000	0.003	0.060	0.078	0.032
April	1968	2010	42	1.84	n/s	0.008	0.000	0.019	0.362	0.572	0.147
May	1968	2010	42	-1.25	n/s	-0.009	-0.023	0.004	1.130	1.417	0.801
June	1968	2010	42	-0.82	n/s	-0.003	-0.009	0.003	0.516	0.642	0.362
July	1968	2010	42	-0.57	n/s	-0.001	-0.003	0.002	0.190	0.249	0.144
August	1968	2010	42	-0.48	n/s	0.000	-0.001	0.001	0.085	0.115	0.065
September	1968	2010	42	-1.17	n/s	0.000	-0.002	0.000	0.067	0.102	0.051
October	1968	2010	42	-0.26	n/s	0.000	-0.001	0.001	0.064	0.085	0.048
November	1968	2010	42	0.21	n/s	0.000	-0.001	0.001	0.064	0.082	0.044
December	1968	2010	42	0.36	n/s	0.000	-0.001	0.001	0.046	0.062	0.035
Annual	1968	2010	42	-0.37	n/s	0.000	-0.003	0.002	0.265	0.310	0.204
January-March	1968	2010	42	1.94	n/s	0.002	0.000	0.005	0.127	0.174	0.085
April-June	1968	2010	42	-0.39	n/s	-0.006	-0.030	0.019	2.313	2.814	1.802
July-September	1968	2010	42	-0.87	n/s	-0.002	-0.006	0.003	0.352	0.466	0.287
October-December	1968	2010	42	0.20	n/s	0.000	-0.002	0.002	0.165	0.231	0.128
08NM174											
January	1971	2010	39	-0.53	n/s	0.000	-0.001	0.001	0.076	0.094	0.063
February	1971	2010	39	-0.15	n/s	0.000	-0.001	0.001	0.085	0.107	0.060
March	1971	2010	39	0.82	n/s	0.001	-0.002	0.003	0.152	0.201	0.094
April	1971	2010	39	2.99	**	0.025	0.010	0.040	0.529	0.675	0.273
May	1971	2010	39	-0.80	n/s	-0.017	-0.067	0.026	3.499	4.717	2.717
June	1971	2010	39	-1.32	n/s	-0.017	-0.048	0.010	1.587	2.350	1.081
July	1971	2010	39	-1.77	n/s	-0.005	-0.012	0.001	0.487	0.609	0.354
August	1971	2010	39	-1.94	n/s	-0.002	-0.004	0.000	0.151	0.199	0.115
September	1971	2010	39	-2.73	**	-0.002	-0.004	-0.001	0.123	0.184	0.086
October	1971	2010	39	-1.05	n/s	-0.001	-0.002	0.001	0.116	0.153	0.089
November	1971	2010	39	-0.39	n/s	0.000	-0.002	0.001	0.115	0.157	0.095
December	1971	2010	39	-0.71	n/s	0.000	-0.002	0.001	0.094	0.118	0.069
Annual	1971	2010	39	-1.02	n/s	-0.003	-0.012	0.004	0.694	0.868	0.523
January-March	1971	2010	39	-0.13	n/s	0.000	-0.004	0.004	0.365	0.447	0.256
April-June	1971	2010	39	-0.40	n/s	-0.016	-0.102	0.057	5.970	8.160	4.420
July-September	1971	2010	39	-2.15	*	-0.011	-0.023	-0.001	0.841	1.076	0.595
October-December	1971	2010	39	-0.59	n/s	-0.001	-0.006	0.003	0.333	0.447	0.265
08NM116											
January	1967	2010	44	-0.40	n/s	-0.001	-0.010	0.010	0.867	1.102	0.749
February	1967	2010	44	0.50	n/s	0.002	-0.008	0.013	0.843	1.039	0.686
March	1967	2010	44	1.02	n/s	0.007	-0.008	0.028	1.208	1.535	0.836
April	1967	2010	44	2.48	*	0.135	0.027	0.236	3.885	6.327	1.741
May	1967	2010	44	-0.60	n/s	-0.050	-0.249	0.142	24.275	29.411	20.101
June	1967	2010	44	-0.55	n/s	-0.091	-0.344	0.142	23.233	28.902	16.201
July	1967	2010	44	-0.97	n/s	-0.039	-0.118	0.040	5.192	7.243	3.071
August	1967	2010	44	-0.19	n/s	-0.002	-0.028	0.017	1.623	2.354	1.150
September	1967	2010	44	-0.92	n/s	-0.010	-0.041	0.015	1.930	2.804	1.443
October	1967	2010	44	-0.36	n/s	-0.005	-0.028	0.021	1.855	2.379	1.483
November	1967	2010	44	0.01	n/s	0.000	-0.024	0.028	1.715	2.109	1.210
December	1967	2010	44	-0.34	n/s	-0.003	-0.016	0.014	1.157	1.422	0.831
Annual	1967	2010	44	-0.81	n/s	-0.021	-0.069	0.029	6.675	7.624	5.254
January-March	1967	2010	44	0.54	n/s	0.012	-0.027	0.044	3.018	4.031	2.389
April-June	1967	2010	44	-0.58	n/s	-0.113	-0.510	0.303	55.950	63.803	46.395
July-September	1967	2010	44	-0.85	n/s	-0.061	-0.212	0.062	9.607	13.952	6.884
October-December	1967	2010	44	-0.31	n/s	-0.008	-0.067	0.061	4.747	6.367	4.151

Time series	First year	Last Year	n	Mann-Kendall trend Test Z[a]	Significance[b]	Sen's slope estimate Q^{c}	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B^{f}	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM134											
January	1966	2010	44	0.39	n/s	0.000	0.000	0.000	0.041	0.046	0.035
February	1966	2010	44	0.20	n/s	0.000	0.000	0.000	0.040	0.045	0.035
March	1966	2010	44	0.38	n/s	0.000	0.000	0.001	0.045	0.053	0.039
April	1966	2010	44	3.14	**	0.005	0.002	0.007	0.112	0.167	0.059
May	1966	2010	44	-0.25	n/s	-0.001	-0.007	0.006	0.659	0.770	0.516
June	1966	2010	44	-1.49	n/s	-0.003	-0.009	0.001	0.355	0.550	0.231
July	1966	2010	44	-1.54	n/s	-0.001	-0.003	0.000	0.132	0.184	0.096
August	1966	2010	44	-1.70	n/s	0.000	-0.001	0.000	0.060	0.089	0.048
September	1966	2010	44	-1.59	n/s	0.000	-0.001	0.000	0.053	0.075	0.044
October	1966	2010	44	-1.47	n/s	0.000	-0.001	0.000	0.051	0.063	0.042
November	1966	2010	44	-0.47	n/s	0.000	0.000	0.000	0.046	0.057	0.038
December	1966	2010	44	-0.09	n/s	0.000	0.000	0.000	0.042	0.052	0.034
Annual	1966	2010	44	-0.54	n/s	0.000	-0.002	0.001	0.148	0.187	0.108
January-March	1966	2010	44	0.38	n/s	0.000	-0.001	0.002	0.131	0.150	0.109
April-June	1966	2010	44	-0.43	n/s	-0.003	-0.015	0.010	1.287	1.593	0.905
July-September	1966	2010	44	-1.56	n/s	-0.002	-0.005	0.000	0.245	0.356	0.197
October-December	1966	2010	44	-0.45	n/s	0.000	-0.001	0.001	0.136	0.168	0.111
08NM241											
January	1984	2010	27	0.71	n/s	0.000	0.000	0.000	0.005	0.008	0.003
February	1984	2010	27	1.02	n/s	0.000	0.000	0.000	0.004	0.005	0.001
March	1984	2010	27	0.61	n/s	0.000	0.000	0.000	0.005	0.008	0.002
April	1984	2010	27	0.83	n/s	0.001	-0.001	0.004	0.050	0.084	0.022
May	1984	2010	27	1.54	n/s	0.004	-0.001	0.010	0.274	0.334	0.192
June	1984	2010	27	0.13	n/s	0.000	-0.007	0.004	0.131	0.254	0.071
July	1984	2010	27	-0.65	n/s	0.000	-0.002	0.001	0.036	0.052	0.020
August	1984	2010	27	-0.52	n/s	0.000	-0.001	0.000	0.009	0.016	0.004
September	1984	2010	27	-0.55	n/s	0.000	0.000	0.000	0.006	0.010	0.004
October	1984	2010	27	0.82	n/s	0.000	0.000	0.001	0.007	0.012	0.003
November	1984	2010	27	0.92	n/s	0.000	0.000	0.001	0.007	0.014	0.002
December	1984	2010	27	0.77	n/s	0.000	0.000	0.000	0.006	0.010	0.003
Annual	1984	2010	27	0.61	n/s	0.000	-0.001	0.001	0.052	0.066	0.038
January-March	1984	2010	27	0.71	n/s	0.000	0.000	0.001	0.014	0.019	0.006
April-June	1984	2010	27	0.92	n/s	0.004	-0.004	0.012	0.479	0.597	0.388
July-September	1984	2010	27	-0.67	n/s	0.000	-0.002	0.001	0.050	0.074	0.038
October-December	1984	2010	27	0.92	n/s	0.000	-0.001	0.001	0.021	0.035	0.008
08NM037											
January	1966	2010	44	1.16	n/s	0.000	0.000	0.001	0.045	0.058	0.037
February	1966	2010	44	1.24	n/s	0.000	0.000	0.001	0.045	0.053	0.034
March	1966	2010	44	0.65	n/s	0.000	0.000	0.001	0.054	0.072	0.044
April	1966	2010	44	1.33	n/s	0.002	-0.001	0.004	0.126	0.194	0.083
May	1966	2010	44	-0.37	n/s	-0.002	-0.021	0.012	1.417	1.934	1.104
June	1966	2010	44	-0.71	n/s	-0.009	-0.036	0.015	1.545	2.340	0.960
July	1966	2010	44	-0.15	n/s	0.000	-0.008	0.005	0.380	0.566	0.260
August	1966	2010	44	0.15	n/s	0.000	-0.002	0.002	0.124	0.194	0.065
September	1966	2010	44	0.24	n/s	0.000	-0.001	0.001	0.079	0.104	0.057
October	1966	2010	44	0.28	n/s	0.000	-0.001	0.001	0.078	0.101	0.061
November	1966	2010	44	0.72	n/s	0.000	0.000	0.001	0.075	0.092	0.067
December	1966	2010	44	1.04	n/s	0.000	0.000	0.001	0.052	0.066	0.047
Annual	1966	2010	44	-0.67	n/s	-0.002	-0.006	0.003	0.418	0.567	0.308
January-March	1966	2010	44	0.81	n/s	0.001	-0.001	0.002	0.146	0.187	0.119
April-June	1966	2010	44	-0.74	n/s	-0.012	-0.053	0.023	3.553	4.603	2.805
July-September	1966	2010	44	-0.15	n/s	-0.001	-0.012	0.007	0.584	0.964	0.379
October-December	1966	2010	44	0.69	n/s	0.001	-0.001	0.003	0.202	0.240	0.169

Time series	First year	Last Year	n	Mann-Kendall trend Test Z[a]	Significance[b]	Sen's slope estimate Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B[f]	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM050											
January	1922	2010	89	-0.94	n/s	-0.027	-0.098	0.026	9.321	13.724	6.279
February	1922	2010	89	0.90	n/s	0.028	-0.035	0.085	9.428	12.041	7.825
March	1922	2010	89	0.61	n/s	0.021	-0.056	0.092	12.727	15.647	9.891
April	1922	2010	89	0.56	n/s	0.019	-0.054	0.097	13.081	16.100	10.307
May	1922	2010	89	0.33	n/s	0.015	-0.078	0.145	15.585	18.690	10.794
June	1922	2010	89	0.91	n/s	0.039	-0.059	0.157	17.169	20.788	12.257
July	1922	2010	89	2.65	**	0.125	0.036	0.216	12.100	15.415	7.931
August	1922	2010	89	2.86	**	0.114	0.041	0.180	10.354	13.995	7.450
September	1922	2010	89	2.85	**	0.089	0.029	0.146	10.637	13.931	7.553
October	1922	2010	89	-0.89	n/s	-0.027	-0.071	0.035	12.762	15.625	8.560
November	1922	2010	89	-2.73	**	-0.070	-0.122	-0.018	11.435	14.419	7.989
December	1922	2010	89	-2.28	*	-0.069	-0.124	-0.007	11.067	14.812	7.731
Annual	1922	2010	89	1.17	n/s	0.031	-0.025	0.095	13.713	15.602	10.784
January-March	1922	2010	89	0.29	n/s	0.025	-0.173	0.213	32.729	42.476	23.715
April-June	1922	2010	89	1.08	n/s	0.159	-0.106	0.443	46.171	52.844	36.047
July-September	1922	2010	89	3.18	**	0.364	0.146	0.564	31.271	44.254	21.773
October-December	1922	2010	89	-2.30	*	-0.193	-0.307	-0.036	38.225	44.629	29.507
08NM002											
January	1915	2010	93	0.10	n/s	0.002	-0.057	0.042	8.807	12.190	6.345
February	1915	2010	93	1.86	n/s	0.049	-0.003	0.117	7.637	9.549	5.805
March	1915	2010	93	1.85	n/s	0.052	-0.003	0.131	11.252	12.770	7.516
April	1915	2010	93	1.52	n/s	0.050	-0.017	0.132	12.472	14.000	8.802
May	1915	2010	93	1.09	n/s	0.056	-0.053	0.178	16.406	22.195	14.516
June	1915	2010	93	0.43	n/s	0.020	-0.083	0.133	20.869	26.483	15.668
July	1915	2010	93	1.52	n/s	0.079	-0.027	0.162	14.939	20.439	10.788
August	1915	2010	93	2.55	*	0.095	0.023	0.156	10.929	14.620	8.344
September	1915	2010	93	3.52	***	0.093	0.047	0.141	9.282	12.123	7.016
October	1915	2010	93	0.38	n/s	0.011	-0.035	0.055	10.178	13.452	7.092
November	1915	2010	93	-1.67	n/s	-0.037	-0.083	0.005	10.185	13.158	7.076
December	1915	2010	93	-1.57	n/s	-0.033	-0.086	0.009	9.833	13.235	7.413
Annual	1915	2010	93	1.61	n/s	0.042	-0.010	0.102	13.937	15.517	11.024
January-March	1915	2010	93	1.51	n/s	0.127	-0.050	0.299	27.516	35.927	20.561
April-June	1915	2010	93	1.41	n/s	0.181	-0.058	0.473	54.084	60.619	43.578
July-September	1915	2010	93	2.63	**	0.271	0.076	0.480	35.221	45.492	25.785
October-December	1915	2010	93	-1.28	n/s	-0.089	-0.209	0.049	33.001	41.098	25.425
08NM171											
January	1971	2010	40	1.26	n/s	0.001	0.000	0.002	0.093	0.115	0.079
February	1971	2010	40	1.24	n/s	0.001	0.000	0.002	0.091	0.109	0.076
March	1971	2010	40	1.93	n/s	0.002	0.000	0.004	0.094	0.137	0.080
April	1971	2010	40	2.75	**	0.025	0.008	0.041	0.371	0.666	0.202
May	1971	2010	40	-0.49	n/s	-0.015	-0.064	0.032	4.381	5.272	3.262
June	1971	2010	40	-1.22	n/s	-0.035	-0.081	0.020	3.551	4.731	2.118
July	1971	2010	40	-1.03	n/s	-0.007	-0.020	0.005	0.707	1.064	0.457
August	1971	2010	40	-1.90	n/s	-0.003	-0.008	0.000	0.237	0.374	0.185
September	1971	2010	40	-1.96	n/s	-0.002	-0.005	0.000	0.198	0.253	0.145
October	1971	2010	40	-0.35	n/s	-0.001	-0.003	0.002	0.195	0.229	0.142
November	1971	2010	40	0.62	n/s	0.001	-0.002	0.003	0.166	0.203	0.121
December	1971	2010	40	0.13	n/s	0.000	-0.001	0.001	0.126	0.152	0.097
Annual	1971	2010	40	-0.94	n/s	-0.005	-0.014	0.007	0.979	1.187	0.713
January-March	1971	2010	40	1.79	n/s	0.003	0.000	0.007	0.307	0.369	0.252
April-June	1971	2010	40	-0.66	n/s	-0.035	-0.127	0.058	8.807	10.905	7.074
July-September	1971	2010	40	-1.43	n/s	-0.014	-0.037	0.005	1.192	1.845	0.887
October-December	1971	2010	40	0.27	n/s	0.001	-0.005	0.007	0.461	0.587	0.379

[a] The absolute value of the test statistic (Z) is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of Z indicates an upward (downward) trend. [b] The smallest significance level α with which the test shows that the null hypothesis of no trend should be rejected. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. [c] The Sen's estimate for the true slope of the linear trend. [d] The lower limit of the 95% confidence interval of Q (α= 0.05). [e] The upper limit of the 95% confidence interval of Q (α= 0.05). [f] Estimate of the constant B in the equation f(Year)=Q×(Year-First Year)+B for a linear trend. [g] Estimate of the constant $B_{min,95}$ in the equation f(Year)=$Q_{min,95}$*(Year-First Year)+$B_{min,95}$ for 95% confidence level of a linear trend. [h] Estimate of the constant $B_{max,95}$ in the equation f(Year)=$Q_{max,95}$*(Year-First Year)+$B_{max,95}$ for 95% confidence level of a linear trend.

Table 3. Summary of non-parametric Mann-Kendall test statistics for historical temporal trends in monthly minimum streamflows at hydrometric stations in the Okanagan River watershed, British Columbia, Canada. Values are in m^3/s/year (Q) and m^3/s (B).

				Mann-Kendall trend		Sen's slope estimate					
Time series	First year	Last Year	n	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B[f]	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM142											
January	1968	2010	42	1.66	n/s	0.000	0.000	0.001	0.031	0.041	0.024
February	1968	2010	42	1.33	n/s	0.000	0.000	0.001	0.032	0.043	0.025
March	1968	2010	42	1.79	n/s	0.001	0.000	0.001	0.035	0.047	0.024
April	1968	2010	42	1.74	n/s	0.003	0.000	0.007	0.099	0.177	0.034
May	1968	2010	42	-1.16	n/s	-0.003	-0.011	0.003	0.545	0.746	0.428
June	1968	2010	42	-0.38	n/s	-0.001	-0.004	0.003	0.281	0.363	0.210
July	1968	2010	42	-0.25	n/s	0.000	-0.001	0.001	0.097	0.126	0.074
August	1968	2010	42	-0.29	n/s	0.000	-0.001	0.001	0.060	0.085	0.042
September	1968	2010	42	-0.62	n/s	0.000	-0.001	0.001	0.049	0.068	0.029
October	1968	2010	42	-0.71	n/s	0.000	-0.001	0.000	0.053	0.070	0.037
November	1968	2010	42	-0.46	n/s	0.000	-0.001	0.000	0.043	0.061	0.033
December	1968	2010	42	0.12	n/s	0.000	0.000	0.001	0.036	0.048	0.030
08NM174											
January	1971	2010	39	0.40	n/s	0.000	-0.001	0.001	0.054	0.065	0.041
February	1971	2010	39	0.02	n/s	0.000	-0.001	0.001	0.065	0.083	0.047
March	1971	2010	39	0.25	n/s	0.000	-0.001	0.001	0.083	0.104	0.062
April	1971	2010	39	1.22	n/s	0.003	-0.001	0.008	0.192	0.308	0.099
May	1971	2010	39	0.75	n/s	0.006	-0.012	0.023	0.959	1.411	0.830
June	1971	2010	39	-1.45	n/s	-0.009	-0.020	0.002	0.804	1.019	0.505
July	1971	2010	39	-1.96	n/s	-0.003	-0.005	0.000	0.198	0.265	0.142
August	1971	2010	39	-2.54	*	-0.002	-0.003	0.000	0.090	0.121	0.067
September	1971	2010	39	-2.83	**	-0.001	-0.003	0.000	0.073	0.116	0.055
October	1971	2010	39	-2.36	*	-0.001	-0.003	0.000	0.086	0.120	0.062
November	1971	2010	39	-1.56	n/s	-0.001	-0.002	0.000	0.085	0.112	0.070
December	1971	2010	39	-0.56	n/s	0.000	-0.001	0.001	0.067	0.096	0.054
08NM116											
January	1967	2010	44	-0.15	n/s	-0.001	-0.008	0.007	0.749	0.877	0.566
February	1967	2010	44	-0.03	n/s	0.000	-0.007	0.007	0.681	0.868	0.563
March	1967	2010	44	0.31	n/s	0.001	-0.007	0.012	0.839	0.984	0.626
April	1967	2010	44	1.06	n/s	0.014	-0.011	0.051	1.506	1.943	0.952
May	1967	2010	44	0.14	n/s	0.011	-0.120	0.170	10.660	13.962	6.583
June	1967	2010	44	0.00	n/s	-0.001	-0.194	0.125	6.859	12.735	3.473
July	1967	2010	44	-0.45	n/s	-0.005	-0.027	0.014	1.363	2.020	0.860
August	1967	2010	44	-0.24	n/s	-0.001	-0.009	0.008	0.739	0.949	0.600
September	1967	2010	44	0.17	n/s	0.001	-0.015	0.009	0.894	1.231	0.614
October	1967	2010	44	-0.07	n/s	-0.001	-0.020	0.013	1.140	1.567	0.849
November	1967	2010	44	-1.15	n/s	-0.005	-0.019	0.007	0.963	1.190	0.807
December	1967	2010	44	-0.62	n/s	-0.003	-0.010	0.007	0.825	1.004	0.667
08NM174											
January	1966	2010	44	0.52	n/s	0.000	0.000	0.000	0.035	0.041	0.029
February	1966	2010	44	0.21	n/s	0.000	0.000	0.000	0.034	0.042	0.026
March	1966	2010	44	0.52	n/s	0.000	0.000	0.000	0.036	0.041	0.029
April	1966	2010	44	0.49	n/s	0.000	0.000	0.001	0.051	0.068	0.041
May	1966	2010	44	0.78	n/s	0.001	-0.002	0.005	0.257	0.342	0.179
June	1966	2010	44	-1.64	n/s	-0.002	-0.004	0.000	0.190	0.248	0.120
July	1966	2010	44	-1.48	n/s	-0.001	-0.002	0.000	0.078	0.104	0.063
August	1966	2010	44	-1.42	n/s	0.000	-0.001	0.000	0.046	0.074	0.035
September	1966	2010	44	-1.20	n/s	0.000	-0.001	0.000	0.042	0.061	0.031
October	1966	2010	44	-1.18	n/s	0.000	-0.001	0.000	0.044	0.055	0.036
November	1966	2010	44	-0.23	n/s	0.000	0.000	0.000	0.038	0.048	0.032
December	1966	2010	44	0.18	n/s	0.000	0.000	0.000	0.034	0.043	0.028

				Mann-Kendall trend		Sen's slope estimate					
Time series	First year	Last Year	n	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B[f]	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM241											
January	1984	2010	27	1.10	n/s	0.000	0.000	0.000	0.004	0.006	0.002
February	1984	2010	27	1.39	n/s	0.000	0.000	0.000	0.003	0.004	0.001
March	1984	2010	27	1.47	n/s	0.000	0.000	0.000	0.003	0.004	0.001
April	1984	2010	27	-0.08	n/s	0.000	0.000	0.000	0.008	0.012	0.004
May	1984	2010	27	2.17	*	0.002	0.000	0.004	0.049	0.076	0.038
June	1984	2010	27	0.35	n/s	0.000	-0.002	0.002	0.036	0.071	0.019
July	1984	2010	27	-0.40	n/s	0.000	-0.001	0.000	0.010	0.016	0.006
August	1984	2010	27	-0.32	n/s	0.000	0.000	0.000	0.002	0.004	0.001
September	1984	2010	27	0.66	n/s	0.000	0.000	0.000	0.002	0.002	0.000
October	1984	2010	27	0.30	n/s	0.000	0.000	0.000	0.002	0.004	0.001
November	1984	2010	27	1.49	n/s	0.000	0.000	0.000	0.004	0.008	0.001
December	1984	2010	27	0.82	n/s	0.000	0.000	0.000	0.005	0.007	0.003
08NM037											
January	1966	2010	44	1.35	n/s	0.000	0.000	0.001	0.037	0.047	0.029
February	1966	2010	44	1.43	n/s	0.000	0.000	0.001	0.034	0.044	0.028
March	1966	2010	44	1.07	n/s	0.000	0.000	0.001	0.039	0.053	0.033
April	1966	2010	44	0.36	n/s	0.000	-0.001	0.001	0.074	0.095	0.056
May	1966	2010	44	0.53	n/s	0.002	-0.005	0.009	0.304	0.469	0.147
June	1966	2010	44	-0.33	n/s	-0.002	-0.013	0.008	0.661	0.941	0.336
July	1966	2010	44	0.17	n/s	0.000	-0.003	0.003	0.162	0.248	0.101
August	1966	2010	44	0.10	n/s	0.000	-0.001	0.001	0.070	0.114	0.034
September	1966	2010	44	0.71	n/s	0.000	-0.001	0.001	0.042	0.063	0.034
October	1966	2010	44	0.53	n/s	0.000	-0.001	0.001	0.048	0.062	0.034
November	1966	2010	44	-0.50	n/s	0.000	-0.001	0.000	0.046	0.063	0.038
December	1966	2010	44	1.06	n/s	0.000	0.000	0.001	0.035	0.043	0.029
08NM050											
January	1922	2010	89	-0.67	n/s	-0.015	-0.067	0.030	6.489	9.603	3.720
February	1922	2010	89	0.40	n/s	0.009	-0.036	0.049	4.963	7.572	3.075
March	1922	2010	89	-0.27	n/s	-0.007	-0.076	0.045	9.833	12.463	7.103
April	1922	2010	89	-0.40	n/s	-0.011	-0.078	0.051	10.219	12.718	7.515
May	1922	2010	89	-1.17	n/s	-0.044	-0.119	0.030	11.218	14.830	8.412
June	1922	2010	89	-0.82	n/s	-0.029	-0.114	0.035	11.265	14.696	9.377
July	1922	2010	89	1.16	n/s	0.045	-0.036	0.111	10.007	15.406	7.227
August	1922	2010	89	1.77	n/s	0.063	-0.008	0.117	9.189	13.893	7.104
September	1922	2010	89	0.22	n/s	0.005	-0.050	0.055	10.012	13.410	6.998
October	1922	2010	89	-1.92	n/s	-0.048	-0.102	0.000	10.710	13.973	7.516
November	1922	2010	89	-2.62	**	-0.062	-0.113	-0.017	9.460	12.963	6.842
December	1922	2010	89	-2.57	*	-0.073	-0.119	-0.014	10.424	13.208	6.391
08NM002											
January	1915	2010	93	-0.52	n/s	-0.011	-0.064	0.024	7.440	11.005	5.359
February	1915	2010	93	0.44	n/s	0.008	-0.033	0.041	5.934	8.504	4.525
March	1915	2010	93	1.11	n/s	0.023	-0.026	0.069	7.434	10.323	5.367
April	1915	2010	93	0.33	n/s	0.008	-0.044	0.060	9.509	11.958	8.100
May	1915	2010	93	-0.23	n/s	-0.010	-0.085	0.061	13.041	16.779	8.318
June	1915	2010	93	-0.70	n/s	-0.026	-0.127	0.041	14.926	20.636	11.586
July	1915	2010	93	0.20	n/s	0.010	-0.071	0.081	13.938	18.154	10.773
August	1915	2010	93	2.36	*	0.066	0.015	0.114	9.243	12.144	7.206
September	1915	2010	93	1.50	n/s	0.034	-0.011	0.075	8.849	11.984	6.331
October	1915	2010	93	-0.46	n/s	-0.009	-0.050	0.030	9.352	12.143	6.773
November	1915	2010	93	-1.68	n/s	-0.030	-0.079	0.004	8.559	11.980	6.010
December	1915	2010	93	-1.84	n/s	-0.036	-0.079	0.002	9.010	11.828	6.451
08NM171											
January	1971	2010	40	1.43	n/s	0.001	0.000	0.002	0.075	0.096	0.058
February	1971	2010	40	2.14	*	0.001	0.000	0.002	0.067	0.085	0.054
March	1971	2010	40	2.06	*	0.001	0.000	0.002	0.078	0.100	0.061
April	1971	2010	40	2.27	*	0.003	0.000	0.007	0.131	0.165	0.072
May	1971	2010	40	1.21	n/s	0.014	-0.008	0.034	1.249	1.606	0.855
June	1971	2010	40	-0.90	n/s	-0.012	-0.031	0.009	1.344	1.814	0.828
July	1971	2010	40	-1.50	n/s	-0.004	-0.009	0.001	0.309	0.438	0.221
August	1971	2010	40	-1.32	n/s	-0.001	-0.004	0.001	0.148	0.214	0.109
September	1971	2010	40	-1.53	n/s	-0.001	-0.003	0.000	0.125	0.163	0.094
October	1971	2010	40	-0.85	n/s	-0.001	-0.002	0.001	0.126	0.159	0.095
November	1971	2010	40	0.85	n/s	0.001	-0.001	0.002	0.107	0.121	0.065
December	1971	2010	40	0.26	n/s	0.000	-0.001	0.002	0.092	0.114	0.072

[a] The absolute value of the test statistic (Z) is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of Z indicates an upward (downward) trend. [b] The smallest significance level α with which the test shows that the null hypothesis of no trend should be rejected. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. [c] The Sen's estimate for the true slope of the linear trend. [d] The lower limit of the 95% confidence interval of Q (α= 0.05). [e] The upper limit of the 95% confidence interval of Q (α= 0.05). [f] Estimate of the constant B in the equation f(Year)=Q×(Year-First Year)+B for a linear trend. [g] Estimate of the constant $B_{min,95}$ in the equation f(Year)=$Q_{min,95}$*(Year-First Year)+$B_{min,95}$ for 95% confidence level of a linear trend. [h] Estimate of the constant $B_{max,95}$ in the equation f(Year)=$Q_{max,95}$*(Year-First Year)+$B_{max,95}$ for 95% confidence level of a linear trend.

Table 4. Summary of non-parametric Mann-Kendall test statistics for historical temporal trends in monthly maximum streamflows at hydrometric stations in the Okanagan River watershed, British Columbia, Canada. Values are in m^3/s/year (Q) and m^3/s (B).

				Mann-Kendall trend		Sen's slope estimate					
Time series	First year	Last Year	n	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B[f]	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM142											
January	1968	2010	42	1.36	n/s	0.001	0.000	0.001	0.042	0.058	0.032
February	1968	2010	42	1.49	n/s	0.001	0.000	0.001	0.043	0.059	0.030
March	1968	2010	42	2.09	*	0.004	0.000	0.008	0.101	0.160	0.008
April	1968	2010	42	0.96	n/s	0.007	-0.011	0.025	1.077	1.410	0.626
May	1968	2010	42	-0.95	n/s	-0.012	-0.035	0.012	1.876	2.252	1.313
June	1968	2010	42	-1.13	n/s	-0.007	-0.020	0.005	0.929	1.256	0.615
July	1968	2010	42	-0.65	n/s	-0.001	-0.005	0.003	0.291	0.408	0.215
August	1968	2010	42	0.26	n/s	0.000	-0.002	0.002	0.135	0.174	0.104
September	1968	2010	42	-1.18	n/s	-0.001	-0.003	0.000	0.116	0.165	0.087
October	1968	2010	42	-0.17	n/s	0.000	-0.001	0.001	0.093	0.120	0.062
November	1968	2010	42	0.95	n/s	0.001	-0.001	0.002	0.070	0.105	0.052
December	1968	2010	42	-0.23	n/s	0.000	-0.001	0.001	0.064	0.083	0.053
08NM174											
January	1971	2010	39	-0.80	n/s	0.000	-0.001	0.001	0.097	0.116	0.081
February	1971	2010	39	0.12	n/s	0.000	-0.001	0.001	0.101	0.127	0.077
March	1971	2010	39	0.53	n/s	0.002	-0.005	0.010	0.262	0.394	0.136
April	1971	2010	39	2.71	**	0.059	0.020	0.099	1.007	1.905	0.591
May	1971	2010	39	-1.34	n/s	-0.063	-0.165	0.034	7.397	9.817	5.456
June	1971	2010	39	-1.31	n/s	-0.036	-0.121	0.017	3.071	5.708	2.120
July	1971	2010	39	-1.48	n/s	-0.009	-0.024	0.004	0.859	1.173	0.661
August	1971	2010	39	-1.78	n/s	-0.003	-0.008	0.000	0.271	0.366	0.207
September	1971	2010	39	-2.36	*	-0.004	-0.009	-0.001	0.232	0.364	0.190
October	1971	2010	39	0.29	n/s	0.000	-0.002	0.003	0.155	0.213	0.127
November	1971	2010	39	0.83	n/s	0.001	-0.002	0.004	0.165	0.210	0.121
December	1971	2010	39	-1.21	n/s	-0.001	-0.002	0.001	0.119	0.145	0.099
08NM116											
January	1967	2010	44	-0.67	n/s	-0.003	-0.014	0.009	1.135	1.379	0.912
February	1967	2010	44	0.80	n/s	0.006	-0.009	0.020	1.021	1.309	0.806
March	1967	2010	44	1.57	n/s	0.016	-0.005	0.075	1.712	2.144	1.169
April	1967	2010	44	1.53	n/s	0.220	-0.083	0.505	13.576	20.018	7.314
May	1967	2010	44	-0.56	n/s	-0.115	-0.415	0.227	45.043	51.769	40.071
June	1967	2010	44	-0.69	n/s	-0.115	-0.503	0.173	43.465	51.308	33.995
July	1967	2010	44	-0.40	n/s	-0.025	-0.253	0.129	12.850	17.589	8.940
August	1967	2010	44	-0.58	n/s	-0.026	-0.105	0.045	4.771	6.626	3.191
September	1967	2010	44	-1.19	n/s	-0.050	-0.130	0.024	5.005	7.149	3.498
October	1967	2010	44	0.13	n/s	0.003	-0.051	0.054	3.049	4.433	2.190
November	1967	2010	44	0.40	n/s	0.010	-0.033	0.063	2.623	3.626	1.648
December	1967	2010	44	-0.74	n/s	-0.007	-0.027	0.016	1.643	2.006	1.223
08NM174											
January	1966	2010	44	0.30	n/s	0.000	0.000	0.000	0.050	0.056	0.041
February	1966	2010	44	-0.24	n/s	0.000	0.000	0.000	0.045	0.054	0.039
March	1966	2010	44	0.54	n/s	0.000	-0.001	0.001	0.063	0.077	0.045
April	1966	2010	44	3.65	***	0.015	0.008	0.022	0.154	0.324	0.034
May	1966	2010	44	0.56	n/s	0.004	-0.011	0.018	1.285	1.465	0.923
June	1966	2010	44	-1.25	n/s	-0.006	-0.023	0.003	0.628	1.242	0.435
July	1966	2010	44	-0.87	n/s	-0.001	-0.004	0.001	0.196	0.275	0.144
August	1966	2010	44	-1.20	n/s	0.000	-0.002	0.000	0.083	0.121	0.064
September	1966	2010	44	-1.58	n/s	-0.001	-0.001	0.000	0.077	0.102	0.059
October	1966	2010	44	-1.77	n/s	0.000	-0.001	0.000	0.064	0.077	0.056
November	1966	2010	44	-0.52	n/s	0.000	-0.001	0.000	0.059	0.071	0.047
December	1966	2010	44	-0.58	n/s	0.000	-0.001	0.000	0.055	0.065	0.044

Time series	First year	Last Year	n	Mann-Kendall trend Test Z[a]	Significance[b]	Sen's slope estimate Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	B[f]	$B_{min,95}$[g]	$B_{max,95}$[h]
08NM241											
January	1984	2010	27	0.44	n/s	0.000	0.000	0.000	0.006	0.009	0.003
February	1984	2010	27	0.74	n/s	0.000	0.000	0.000	0.005	0.007	0.002
March	1984	2010	27	0.21	n/s	0.000	0.000	0.000	0.008	0.012	0.003
April	1984	2010	27	1.40	n/s	0.005	-0.002	0.018	0.160	0.281	0.043
May	1984	2010	27	0.42	n/s	0.003	-0.015	0.024	0.809	1.038	0.711
June	1984	2010	27	-0.54	n/s	-0.004	-0.021	0.009	0.409	0.685	0.196
July	1984	2010	27	-0.79	n/s	-0.001	-0.004	0.002	0.078	0.140	0.056
August	1984	2010	27	-0.33	n/s	0.000	-0.002	0.001	0.030	0.047	0.011
September	1984	2010	27	-0.90	n/s	0.000	-0.001	0.001	0.026	0.036	0.015
October	1984	2010	27	0.10	n/s	0.000	-0.001	0.001	0.018	0.029	0.011
November	1984	2010	27	1.00	n/s	0.000	0.000	0.001	0.012	0.021	0.000
December	1984	2010	27	0.77	n/s	0.000	0.000	0.000	0.007	0.012	0.003
08NM037											
January	1966	2010	44	0.43	n/s	0.000	-0.001	0.001	0.057	0.076	0.049
February	1966	2010	44	0.38	n/s	0.000	-0.001	0.001	0.064	0.081	0.047
March	1966	2010	44	0.23	n/s	0.000	-0.001	0.001	0.081	0.101	0.065
April	1966	2010	44	1.70	n/s	0.006	-0.002	0.014	0.300	0.464	0.103
May	1966	2010	44	0.36	n/s	0.008	-0.040	0.054	3.105	4.115	2.402
June	1966	2010	44	-0.83	n/s	-0.018	-0.076	0.020	3.236	4.838	2.293
July	1966	2010	44	-0.52	n/s	-0.003	-0.017	0.008	0.835	1.312	0.620
August	1966	2010	44	0.83	n/s	0.002	-0.003	0.005	0.183	0.334	0.114
September	1966	2010	44	0.23	n/s	0.000	-0.002	0.003	0.132	0.183	0.095
October	1966	2010	44	0.52	n/s	0.000	-0.001	0.002	0.111	0.143	0.099
November	1966	2010	44	1.15	n/s	0.001	-0.001	0.002	0.106	0.130	0.082
December	1966	2010	44	0.69	n/s	0.000	0.000	0.001	0.074	0.089	0.059
08NM050											
January	1922	2010	89	-1.01	n/s	-0.034	-0.101	0.034	12.329	15.208	9.401
February	1922	2010	89	0.90	n/s	0.032	-0.051	0.113	13.535	16.903	10.447
March	1922	2010	89	1.31	n/s	0.064	-0.036	0.150	16.080	17.122	12.750
April	1922	2010	89	1.14	n/s	0.048	-0.042	0.153	15.734	18.960	12.034
May	1922	2010	89	1.39	n/s	0.108	-0.040	0.280	18.734	24.361	12.835
June	1922	2010	89	3.12	**	0.240	0.092	0.402	19.128	23.033	12.959
July	1922	2010	89	3.83	***	0.230	0.104	0.374	12.301	17.714	7.081
August	1922	2010	89	3.56	***	0.165	0.088	0.285	12.782	15.223	6.949
September	1922	2010	89	3.91	***	0.168	0.093	0.258	10.101	13.469	7.338
October	1922	2010	89	0.16	n/s	0.006	-0.045	0.060	13.822	16.104	11.021
November	1922	2010	89	-2.09	*	-0.071	-0.127	-0.005	14.285	17.144	9.923
December	1922	2010	89	-1.65	n/s	-0.059	-0.130	0.009	13.434	17.180	9.484
08NM002											
January	1915	2010	93	0.34	n/s	0.008	-0.061	0.066	10.430	14.601	6.809
February	1915	2010	93	2.09	*	0.085	0.006	0.158	11.358	14.155	9.169
March	1915	2010	93	2.21	*	0.081	0.009	0.170	14.007	16.032	10.730
April	1915	2010	93	1.82	n/s	0.077	-0.006	0.188	15.983	18.472	10.091
May	1915	2010	93	1.44	n/s	0.100	-0.038	0.267	25.100	28.326	17.794
June	1915	2010	93	2.30	*	0.163	0.023	0.324	26.135	30.132	18.463
July	1915	2010	93	2.34	*	0.125	0.021	0.268	18.603	23.351	12.745
August	1915	2010	93	2.52	*	0.116	0.036	0.205	12.585	16.826	9.441
September	1915	2010	93	4.34	***	0.155	0.091	0.222	9.038	12.004	6.388
October	1915	2010	93	1.08	n/s	0.033	-0.023	0.073	11.040	14.652	7.973
November	1915	2010	93	-1.50	n/s	-0.038	-0.088	0.012	12.354	15.666	9.186
December	1915	2010	93	-1.40	n/s	-0.039	-0.105	0.011	11.964	15.909	9.150
08NM171											
January	1971	2010	40	0.87	n/s	0.001	-0.001	0.003	0.115	0.136	0.099
February	1971	2010	40	0.17	n/s	0.000	-0.001	0.002	0.122	0.142	0.098
March	1971	2010	40	1.72	n/s	0.002	-0.001	0.008	0.153	0.198	0.081
April	1971	2010	40	2.12	*	0.057	0.007	0.110	1.588	2.495	0.778
May	1971	2010	40	-1.40	n/s	-0.084	-0.250	0.044	11.574	15.270	8.848
June	1971	2010	40	-1.40	n/s	-0.078	-0.243	0.027	7.181	12.330	5.151
July	1971	2010	40	-0.48	n/s	-0.010	-0.046	0.020	1.478	2.488	0.891
August	1971	2010	40	-1.58	n/s	-0.006	-0.016	0.001	0.473	0.733	0.312
September	1971	2010	40	-2.31	*	-0.008	-0.014	-0.001	0.470	0.600	0.380
October	1971	2010	40	-0.16	n/s	-0.001	-0.006	0.005	0.313	0.427	0.211
November	1971	2010	40	0.86	n/s	0.002	-0.003	0.008	0.224	0.315	0.157
December	1971	2010	40	-0.29	n/s	0.000	-0.002	0.002	0.159	0.201	0.139

[a] The absolute value of the test statistic (Z) is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of Z indicates an upward (downward) trend. [b] The smallest significance level α with which the test shows that the null hypothesis of no trend should be rejected. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. [c] The Sen's estimate for the true slope of the linear trend. [d] The lower limit of the 95% confidence interval of Q (α= 0.05). [e] The upper limit of the 95% confidence interval of Q (α= 0.05). [f] Estimate of the constant B in the equation f(Year)=Q×(Year-First Year)+B for a linear trend. [g] Estimate of the constant $B_{min,95}$ in the equation f(Year)=$Q_{min,95}$*(Year-First Year)+$B_{min,95}$ for 95% confidence level of a linear trend. [h] Estimate of the constant $B_{max,95}$ in the equation f(Year)=$Q_{max,95}$*(Year-First Year)+$B_{max,95}$ for 95% confidence level of a linear trend.

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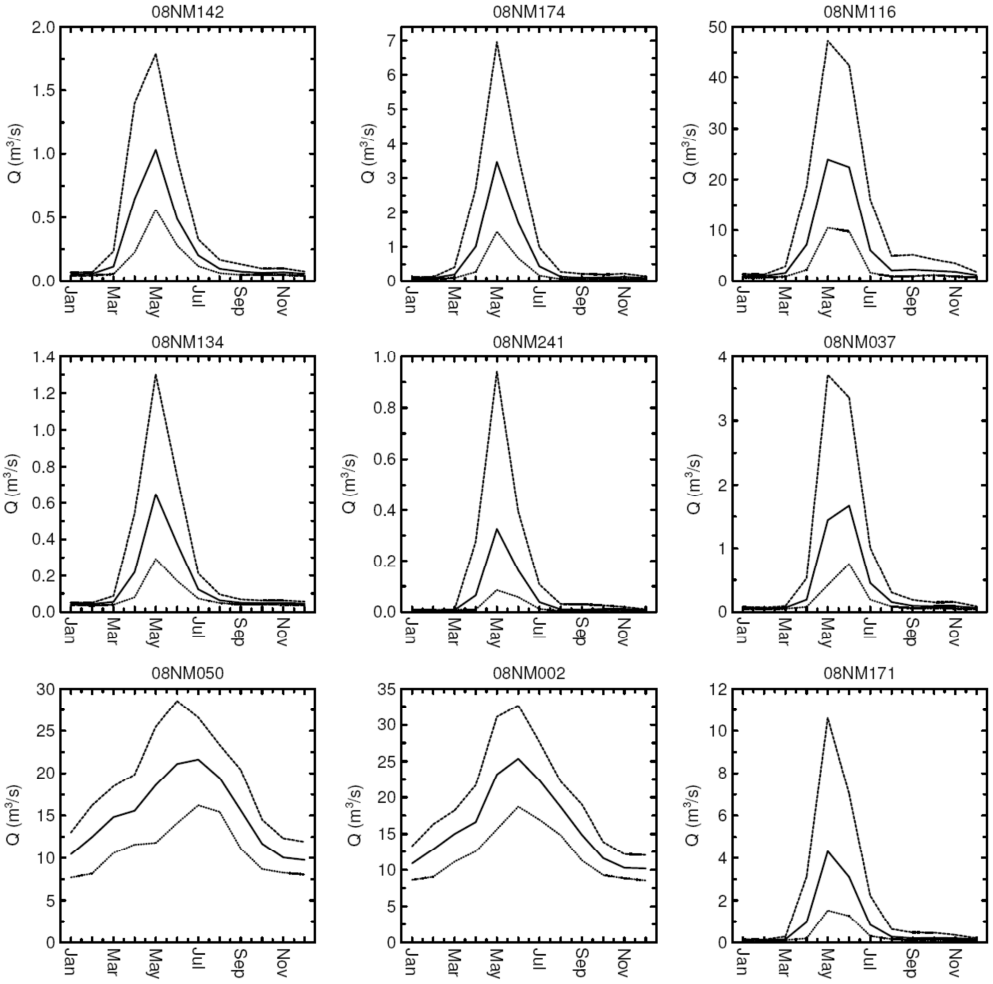

Figure 3. Mean monthly streamflows (solid lines), mean monthly minimum streamflows (dotted lines), and mean monthly maximum streamflows (dashed lines) at each station over their respective available hydrometric records.

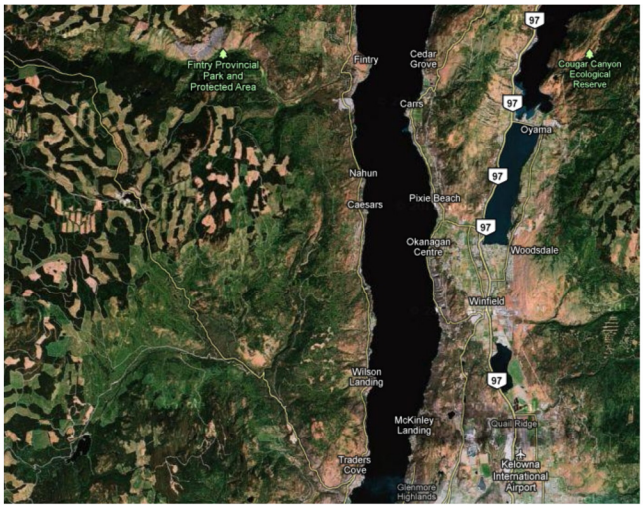

Figure 4. Representative satellite imagery showing the extent of logging activities in the Okanagan River watershed near Kelowna, BC, Canada.

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Table 5. Summary of the historical trends in mean monthly, seasonal, and annual streamflows, as well as minimum and maximum monthly streamflows, at various hydrometric monitoring stations in the Okanagan River watershed, British Columbia, Canada. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. (+)=increasing trend. (–)=decreasing trend.

mean flow	*08NM142*	*08NM174*	*08NM116*	*08NM134*	*08NM241*	*08NM037*	*08NM050*	*08NM002*	*08NM171*
January	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
February	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
March	* (+)	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
April	n/s	** (+)	* (+)	** (+)	n/s	n/s	n/s	n/s	** (+)
May	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
June	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
July	n/s	n/s	n/s	n/s	n/s	n/s	** (+)	n/s	n/s
August	n/s	n/s	n/s	n/s	n/s	n/s	** (+)	* (+)	n/s
September	n/s	** (–)	n/s	n/s	n/s	n/s	** (+)	*** (+)	n/s
October	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
November	n/s	n/s	n/s	n/s	n/s	n/s	** (–)	n/s	n/s
December	n/s	n/s	n/s	n/s	n/s	n/s	* (–)	n/s	n/s
Annual	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
January-March	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
April-June	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
July-September	n/s	* (–)	n/s	n/s	n/s	n/s	** (+)	** (+)	n/s
October-December	n/s	n/s	n/s	n/s	n/s	n/s	* (–)	n/s	n/s
minimum flow	*08NM142*	*08NM174*	*08NM116*	*08NM134*	*08NM241*	*08NM037*	*08NM050*	*08NM002*	*08NM171*
January	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
February	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	* (+)
March	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	* (+)
April	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	* (+)
May	n/s	n/s	n/s	n/s	* (+)	n/s	n/s	n/s	n/s
June	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
July	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
August	n/s	* (–)	n/s	n/s	n/s	n/s	n/s	* (+)	n/s
September	n/s	** (–)	n/s	n/s	n/s	n/s	n/s	n/s	n/s
October	n/s	* (–)	n/s	n/s	n/s	n/s	n/s	n/s	n/s
November	n/s	n/s	n/s	n/s	n/s	n/s	** (–)	n/s	n/s
December	n/s	n/s	n/s	n/s	n/s	n/s	* (–)	n/s	n/s
maximum flow	*08NM142*	*08NM174*	*08NM116*	*08NM134*	*08NM241*	*08NM037*	*08NM050*	*08NM002*	*08NM171*
January	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
February	n/s	n/s	n/s	n/s	n/s	n/s	n/s	* (+)	n/s
March	* (+)	n/s	n/s	n/s	n/s	n/s	n/s	* (+)	n/s
April	n/s	** (+)	n/s	*** (+)	n/s	n/s	n/s	n/s	* (+)
May	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
June	n/s	n/s	n/s	n/s	n/s	n/s	** (+)	* (+)	n/s
July	n/s	n/s	n/s	n/s	n/s	n/s	*** (+)	* (+)	n/s
August	n/s	n/s	n/s	n/s	n/s	n/s	*** (+)	* (+)	n/s
September	n/s	* (–)	n/s	n/s	n/s	n/s	*** (+)	*** (+)	* (–)
October	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
November	n/s	n/s	n/s	n/s	n/s	n/s	* (–)	n/s	n/s
December	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s

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